AN EVALUATION OF FOREST SOIL TILLAGE USING THE WINGED SUBSOILER ON LANDINGS IN THE PRINCE GEORGE FOREST DISTRICT

A Pilot Study

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Contract Report

Silviculture Branch

Ministry of Forests

Victoria, B.C.

1989

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1.0 INTRODUCTION

Timber harvesting with ground-based equipment necessitates the construction of skid roads and landings, which by altering soil characteristics can adversely affect site productivity. The removal of nutrient-rich surface soil horizons dramatically lowers site nutrient capital, particularly of nitrogen and phosphorus (Arnott et al. 1988, Carr 1987b). Additionally, the residual soil density in these areas may be 30 to 80% higher due to soil compaction and/or the exposing of high density subsoil. Higher soil density results in increased resistance to root penetration and changes in macropore-micropore relationships (Greacan and Sands 1980). The result of soil scalping and high residual soil density is often decreased forest productivity (Arnott et al. 1988, Carr 1987b, Froehlich 1979, Jakobsen 1983, Perry 1964, Wert and Thomas 1981).

In general, landings may occupy 3 to 5% of cutover land, while the area in skid roads and skid trails may range from 10% to in excess of 30%. The potential for reduced site productivity on this portion of cutover land may have severe economic implications in the future (Utzig and Walmsley 1988). Changes in harvesting systems and layout can reduce the area potentially degraded by ground-based logging. However, soil rehabilitation presents the only post-logging option for minimizing the productivity impacts.

Soil rehabilitation guidelines, primarily directed at landings, exist in all the Interior forest regions. A key component of this rehabilitation is ripping (or tillage) of compacted soil to a depth of 30cm. The tillage implements commonly used in British Columbia are brush blades and rock rippers. However, the effectiveness of these implements in creating suitable soil conditions for tree growth is questionable (Andrus and Froehlich 1983). Standard ripping implements were found to be far from satisfactory in soil decompaction and profile shatter during an evaluation of landing rehabilitation activities in the Prince George East Forest District (Carr 1985, unpublished contract report).

The development of a new soil tillage implement for forestry application, the self-drafting winged subsoiler by Tilth Inc. (Monroe, Oregon), has stimulated considerable interest among foresters in California, Oregon, Washington, and British Columbia. Early test results from Oregon were very positive (Froehlich and Miles 1984). In 1985, the Silviculture Branch (MOF) initiated a limited trial of the winged subsoiler on landings near Prince George. Evaluation of the ripping effectiveness was conducted in late 1985, with continued monitoring in 1986 and 1988. The results of this trial are presented in this report.

2.0 OBJECTIVE

The objective of the landing ripping trial conducted by the Silviculture Branch was to provide an evaluation of the tillage effectiveness of the winged subsoiler in the Prince George Forest District. The parameters used in defining tillage effectiveness are: change in soil bulk density, depth and pattern of soil shatter, and residual clod distribution (Andrus 1982). Evaluation of initial tillage effectiveness was followed by subsequent monitoring of soil density to assess potential soil reconsolidation.

3.0 SCOPE

Due to budget limitations, only three landings were assessed from the initial operational tillage trial. These landings represented different soil textures within the study area. A further complication is that the evaluation of tillage effectiveness was initiated three months after the operation was completed, which may make comparisons with other studies difficult. It must be remembered that this was a pilot program to begin the evaluation of the winged subsoiler, the use of which has expanded in both the Prince George, Cariboo, and Prince Rupert Forest Regions. Efforts are being made to continue a monitoring program on all early soil tillage operations.

4.0 MATERIALS AND METHODS

4.1 Study Area

In August 1985, the Silviculture Branch (MOF-Victoria) contracted a local operator with a D-7 Caterpiller tractor to rip various landings in the Prince George Forest District using a winged subsoiler supplied by Ed Fields (Tilth Inc., Monroe, Oregon). Of these landings, three were selected for evaluation of tillage effectiveness. These are located on the Beaver Forest Road, approximately 45km east of Prince George. The selected landings are #6 at 71k (a very gravelly loam to silt-loam texture, with approximately 32% coarse and 26 % fine gravel by weight), #7 at 72k (a very gravelly silt-loam texture, with approximately 24% coarse and 28% fine gravel by weight), and #29 at 59k (a silty clay to silty clay loam texture, with approximately 20% coarse and 5% fine gravel by weight).

4.2 Sampling Procedures

On each landing, three sampling locations were located for monitoring so that sampling of paired non-tilled (control) and tilled (subsoiled) soil was possible. The control areas were left untilled during the subsoiling operation. Soil density was initially measured in 1985, with follow-up assessment in 1986 and 1988. Soil shatter profile and clod-size distribution were determined in 1985.

Soil bulk density was determined using a single-probe nuclear densimeter (Pacific Campbell MC-1) with probe depths at 10cm and 30cm. Standard procedures were used for the calculation of soil bulk density by the densimeter, which was subsequently corrected for coarse fragment content to yield the density of the fine fraction (<2mm) which is that portion of the soil relevant to rooting characteristics. The soil density reassessment in 1986 and 1988 was conducted within 2m of the 1985 test locations.

Ref. for using FRESD

(Note:The earlier drafts of this report did not incorporate the correction of soil density for coarse fragment content. There is some question as to the more appropriate presentation of soil density data, therefore the total soil density data is presented in the appendix for reference.).

To evaluate the soil shatter profile of the winged subsoiler, a 2m long by 1m deep trench (perpendicular to the direction of ripping) was excavated using a backhoe. The face of the trench was trimmed allowing for easy observation of the zone of shatter. The shatter profile was traced on 0.003mm clear acetate mounted on a 1.75m x 0.90m plexiglass "window". The tracing was later used to determine minimum and maximum tillage depths, shape of tillage pattern, and percentage of area affected (based on a desired 30cm rooting zone).

Two shovel-size samples of soil were removed from the face of the excavated trench and sieved to determine the resulting clod-size distribution. This parameter gives an indication of resulting soil structure and aggregation. The sieve sizes used were 50mm, 25mm, 10mm, and 2mm. After sieving and weighing in the field, a subsample of each was brought back for soil moisture and rock content correction.

Analysis of the soil data from each landing for individual years was conducted using a t-test for meaningfully paired samples. For the final data analysis of overall trends, analysis-of-variance using a split-plot model for repeated measurements was used. The main factors were block (landing) and treatment (ripped or control). The split-plot factor was year of sampling. This type of analysis is common in agriculture experimentation where measurements are repeated over time on the same plots (Little and Hills 1978).

5.0 RESULTS AND DISCUSSION

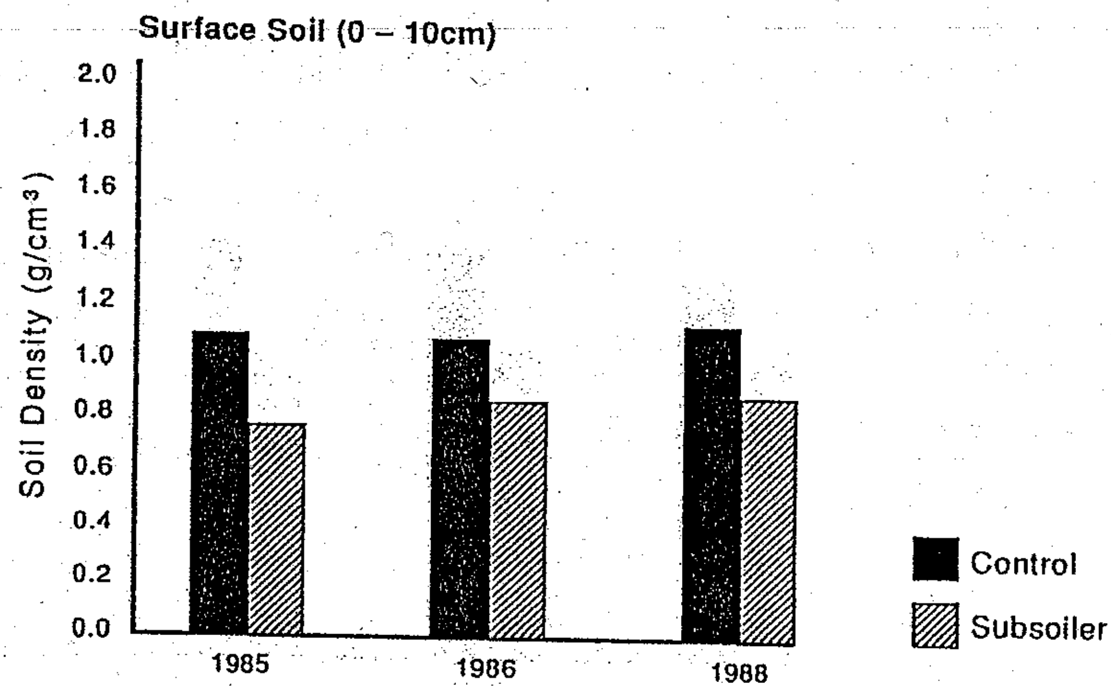
5.1 Soil Bulk Density

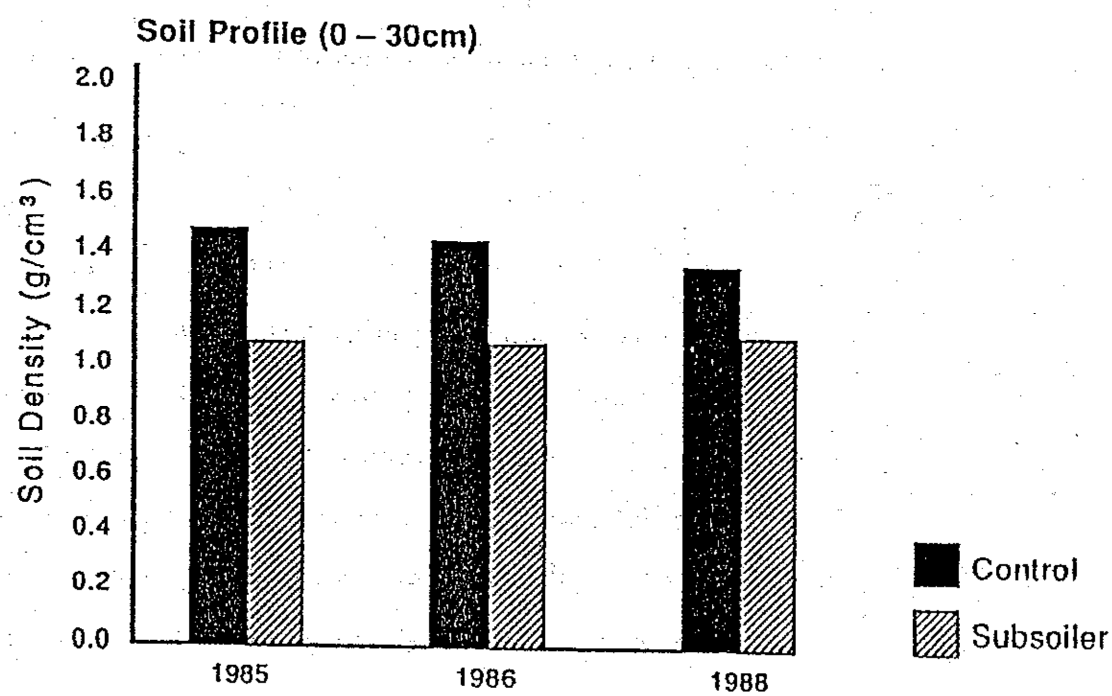
The soil density in both the surface soil (0-10cm) and the overall profile (0-30cm) was significantly reduced by wing subsoiling for each landing (Figure 1, 2, and 3). This reduction, which ranged from 13 to 24 % in the surface soil layer and 7 to 22 % for the overall profile, appears to be dependent on soil texture of the landings. Landing #6, the coarsest soil texture, exhibited the greatest effect of soil tillage. As the soil texture became less coarse, the overall impact of the tillage declined, particularly on Landing #29. Soils with a significant gravel content and coarse texture can more easily transfer the soil tillage energy of the ripper wings through the soil, while finer textured soils are more apt to mould around the wings. This demonstrates the need to consider soil texture in the planning of soil tillage operations. One solution to this problem may the use of a subsoiler wing pattern that exerts more force on the soil.

The analysis-of-variance indicated not only a significant landing and treatment effect, but also a temporal nature to the effectiveness of the decompaction. The split-plot factor of year was significant at a 90% level of confidence, and indicated a trend toward some level of soil reconsolidation. As illustrated in Figure 4, the decrease in soil density achieved by tillage was greatest immediately after tillage, 24% in the soil surface and 17% for the overall profile. By 1988, the decrease in soil density had fallen to 18% in the surface layer and 13% for

Comparison of soil density over time between subsoiled and control areas on landings in Prince George Forest District.

LANDING # 6

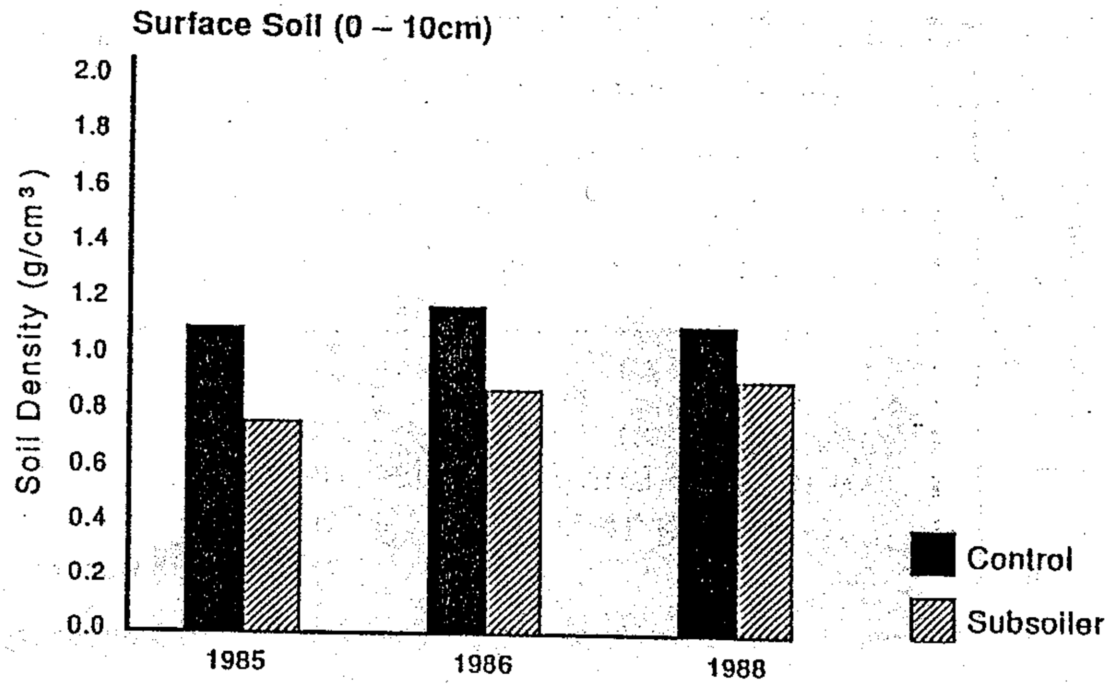


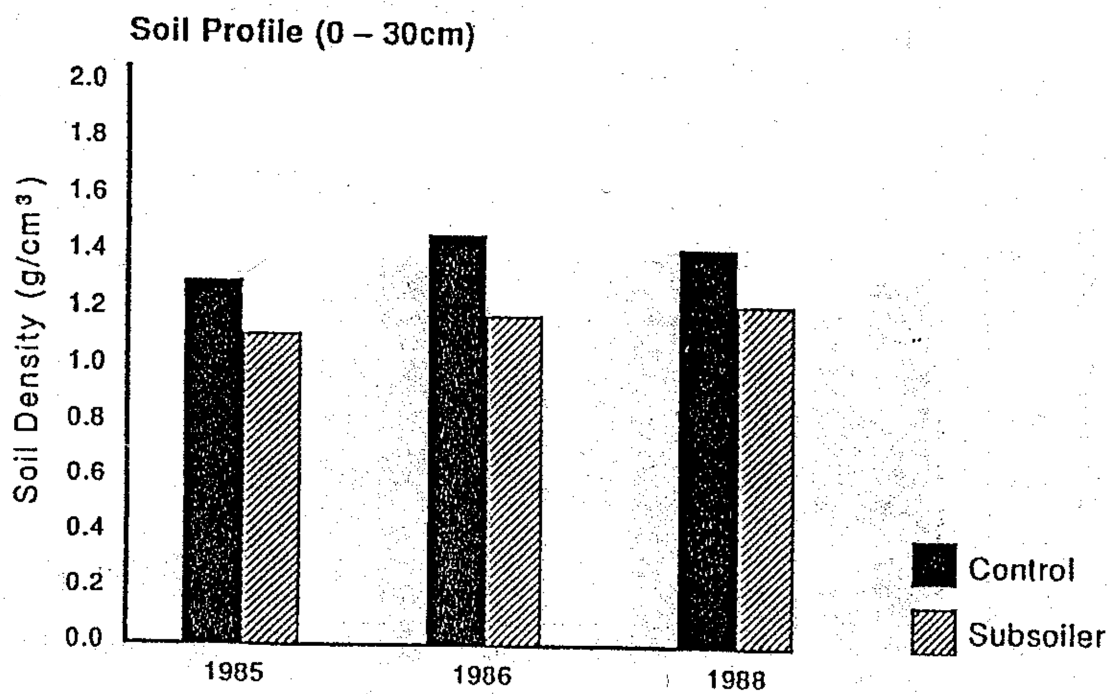


Note: Difference between subsoil and control areas is significant at 95% level of confidence.

Comparison of soil density over time between subsoiled and control areas on landings in Prince George Forest District.

LANDING # 7

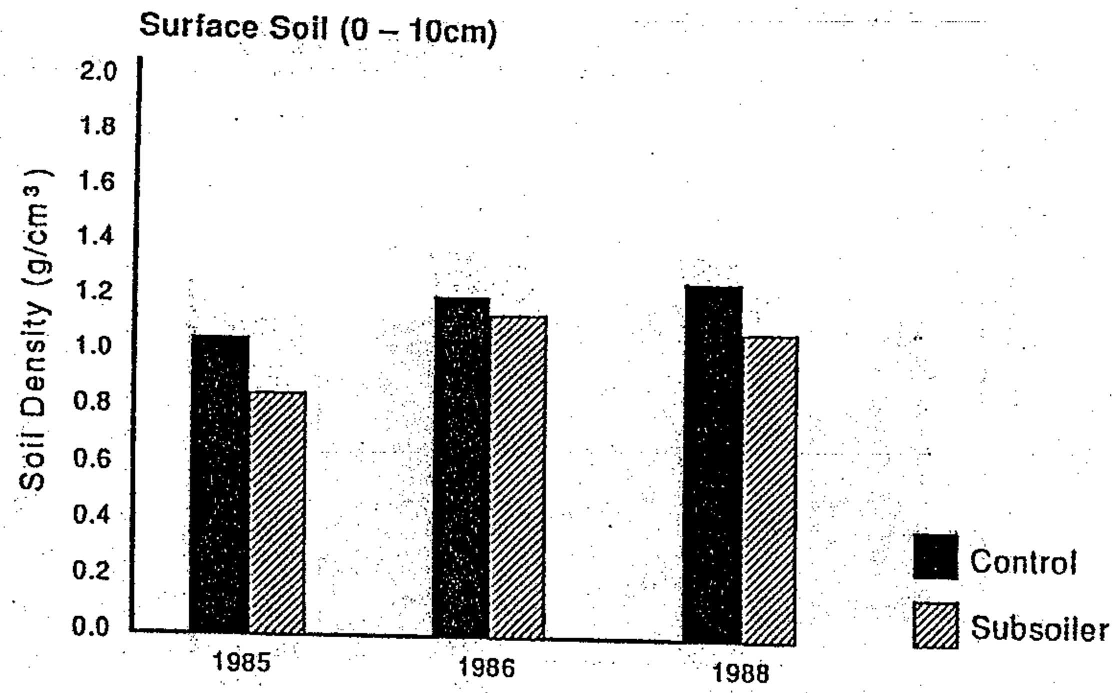


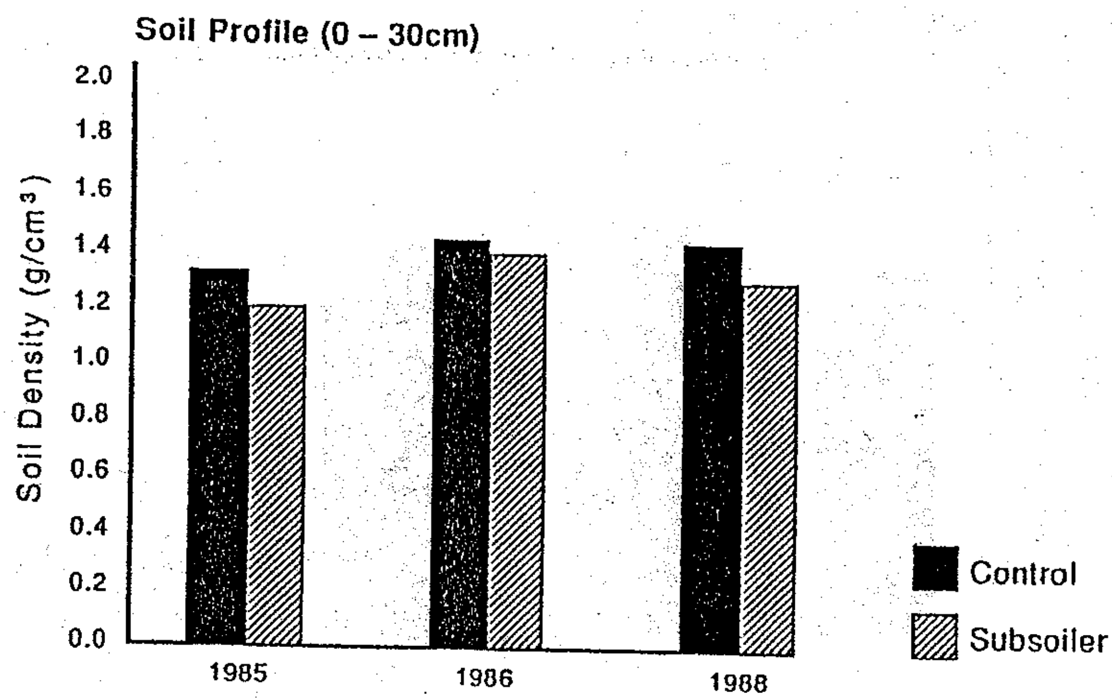


Note: Difference between subsoil and control areas is significant at 95% level of confidence.

Comparison of soil density over time between subsoiled and control areas on landings in Prince George Forest District.

LANDING # 29

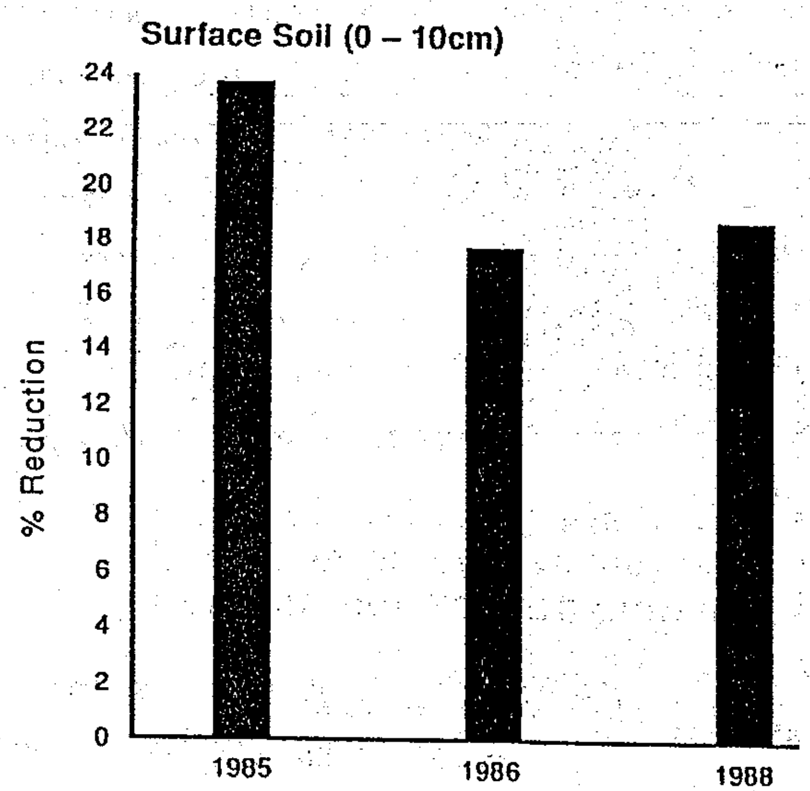


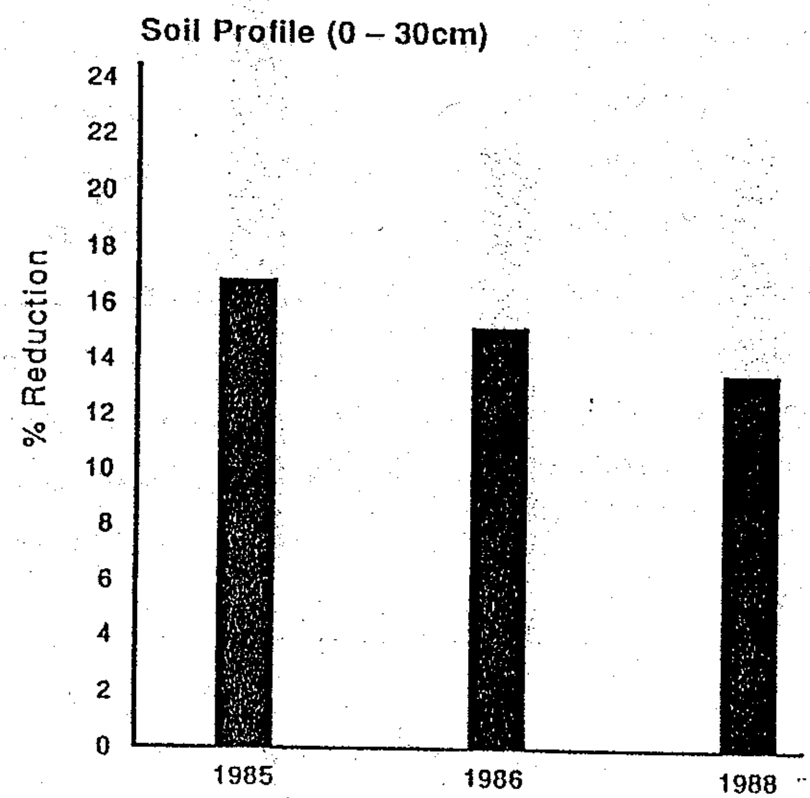


Note: Difference between subsoil and control areas is significant at 95% level of confidence.

The effect of soil reconsolidation over time based on percent reduction in soil density between control and subsoiled areas.

ALL LANDINGS





Note: Difference over time is significant at 90% level of confidence.

the overall soil profile. The benefits of soil tillage are time dependant, even in agriculture (Carter 1988), unless measures are taken to enhance soil aggregate structure and stability. Organic matter additions through root and detritus input from cover crops not only promote formation of stable soil structure, but also enhance soil nutrient capital (Carr 1987a). Soil tillage on its own is not the long-term solution for recovery of productivity on degraded forest soils.

5.2 Soil Shatter Profile

The measures pertinent to describing the degree of profile shatter are presented in Table 1. The average maximum depth of ripping in the furrow was 53cm and the average minimum depth between the tines was 25cm. Based on a 30cm desired average depth of ripping, the profile shatter was 137%. This result, illustrated in Figure 5, exceeds that reported in Andrus and Froehlich (1983) for initial winged subsoiler trials in Oregon, and far exceeds the results achieved (26% shatter) with standard rippers on similar soil in the Pitoney Lake assessment (Carr 1985, unpublished). A 70% profile shatter is deemed the minimum for acceptable tillage in Oregon (Froehlich and Miles 1984).

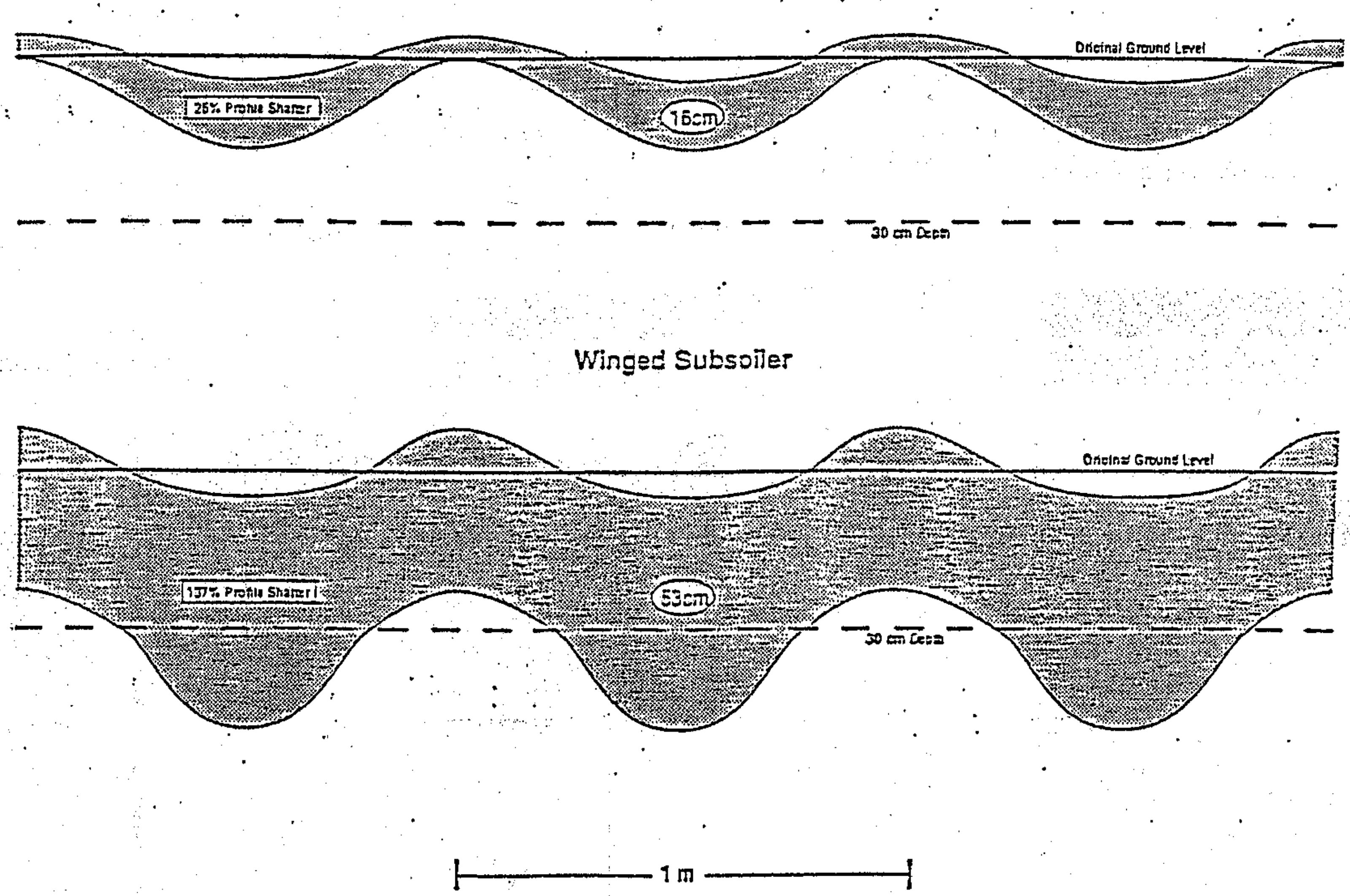
TABLE 1: Soil shatter description of the winged subsoiler

Tillage Depth

	Average	Range
Maximum	53 cm	42-68cm
Minimum	25cm	18-36cm
Overall	41cm	32-51cm

Percent Profile Shatter (based on 30cm)	137%

Figure 5 Comparison of soil shatter profiles for a standard ripper (Carr 1985, unpublished) and the winged subsoiler on similar soil types.



5.3 Clod Size Distribution

The clod size distribution data presented in Table 2 parallels the distribution pattern observed at Pitoney Lake. The high percentage of soil mass in large clods (75cm dia.) three months after tillage indicates a strong tendency toward reconsolidation. The subsoil material exposed during landing construction is inherently low in organic matter content, the primary agent in the formation of stable soil aggregates. Without some organic matter input, reconsolidation can continue and, as is evident from the soil density data illustrated in Figure 4, this appears to have occurred.

Two options exist for countering soil reconsolidation, both involving soil organic matter. Efforts to stockpile the forest floor and top 10-15cm of soil during landing construction must be improved. This soil can be respread as the landing rehabilitation guidelines propose, benefiting both soil physical structure and nutrient levels. If stockpiling is not feasible, the rapid establishment of a high biomass producing cover crop (legumes and grasses) is necessary to enhance soil structure (Carr 1987a). Without efforts to bolster soil organic matter levels, the benefits of soil tillage operations will probably be short lived.

TABLE 2 Clod size distribution as a percentage of soil mass

Beaver Road

Landing	Clod Size (cm)				
	>5	4.99-1.91	1.90-0.95	0.94-0.40	<0.40
#6	88	6	4	1	1
#7	87	6	4	2	1
#29	68	15	9	5	3

Pitoney Lake

Ave.	72	12	6	5	5

6.0 CONCLUSION

Soil tillage with the winged subsoiler accomplished two of the objectives of landing rehabilitation, reducing soil density and achieving satisfactory profile shatter. The results from the Beaver Road trial exceeded those achieved in Oregon (Andrus and Froehlich 1983), and were far superior to the results achieved with a standard ripper on similar soil at Pitoney Lake. The winged subsoiler appears to be a soil tillage implement that is suitable for use on compact forest soils, an opinion shared by forestry staff at Oregon State University (Pers. comm., P. Adams., OSU extension forester). Future studies must focus on identifying soil types where the benefits of tillage operations are most effective and enduring.

Soil tillage is not the sole solution to recovery of productivity on compact degraded forest soils. It is an important step that must be augmented by some form of soil organic matter management. Without the maintenance of soil organic matter, the benefits of soil tillage tend to be short-lived, and nutrient levels generally remain exceedingly low.

7.0 LITERATURE CITED

Andrus, C.W. 1982 (unpublished). Tillage of compacted forest soils following ground-based logging in Oregon. M.Sc. Thesis, Oregon State University, Corvallis, Oregon. 148 pp.

Andrus, C.W. and H.A. Froehlich. 1983. An evaluation of four implements used to till compacted forest soils in the Pacific Northwest. Research Bulletin 45, Forest Research Lab., Oregon State University, Corvallis, Oregon. 12 pp.

Arnott, J.T., W.W. Carr, and A.C. Waines. 1988. Establishing forest cover on winter landings in the Central Interior of British Columbia. For. Chron. 64(2): 121-126.

Carr, W.W. 1987a. Restoring productivity on degraded forest soils: two case studies. FRDA Report 002, B.C. Min. For., Victoria. 21 pp.

Carr, W.W. 1987b. The effect of landing construction on some forest soil properties: a case study. FRDA Report 003, B.C. Min. For., Victoria. 20 pp.

Carr, W.W. 1985 (unpublished). Assessment of landing rehabilitation activities in the Prince George East Forest District. Contract report for Prince George East Forest District, Prince George, B.C. 14 pp.

Carter, M.R. 1988. Penetration resistance to characterize the depth and persistance of soil loosening in tillage studies. Can. J. Soil Sci. 68:657-668.

Daddow, R.L. and G.E. Warrington. 1983. The influence of soil texture on growth-limiting soil bulk densities. Proc. Soc. Am. For.(1983): 252-256.

Froehlich, H.A. 1979. Soil compaction from logging equipment: Effects on growth of young ponderosa pine. J. Soil Water Conserv. 34:276-278.

Froehlich, H.A. and D.W.R. Miles. 1984. Winged subsoiler tills compacted forest soil. Forest Industries: February 1984. 2 pp.

Greacan, E.L. and R. Sands. 1980. Compaction of forest soils, a review. Aust. J. Soil Res. 18:163-189.

Jakobsen, B.F. 1983. Persistance of compaction effects in a Forest Kraznozem. Aust. For. Res. 13:305-308.

Little, T.M. and F.J. Hills. 1978. Agriculture Experimentation. John Wiley and Sons Ltd.

Perry, T.O. 1964. Soil compaction and loblolly pine growth. USFS Tree Planting Notes. 67-69 pp.

Wert S. and B.R. Thomas. 1981. Effects of skid roads on diameter, height, and volume growth in Douglas-fir. Soil Sci. Soc. Am. J. 45:629-632.

Utzig, G.F. and M.E. Walmsley. 1988 Evaluation of soil degradation as a factor affecting forest productivity in British Columbia: A problem analysis, Phase 1. FRDA Report 025, Canadian Forestry Service, Victoria. 111 pp.

APPENDIX

Presentation of gross soil bulk density data before correction for coarse fragment content.

Comparison of soil density over time between subsoiled and control areas on landings in Prince George Forest District.

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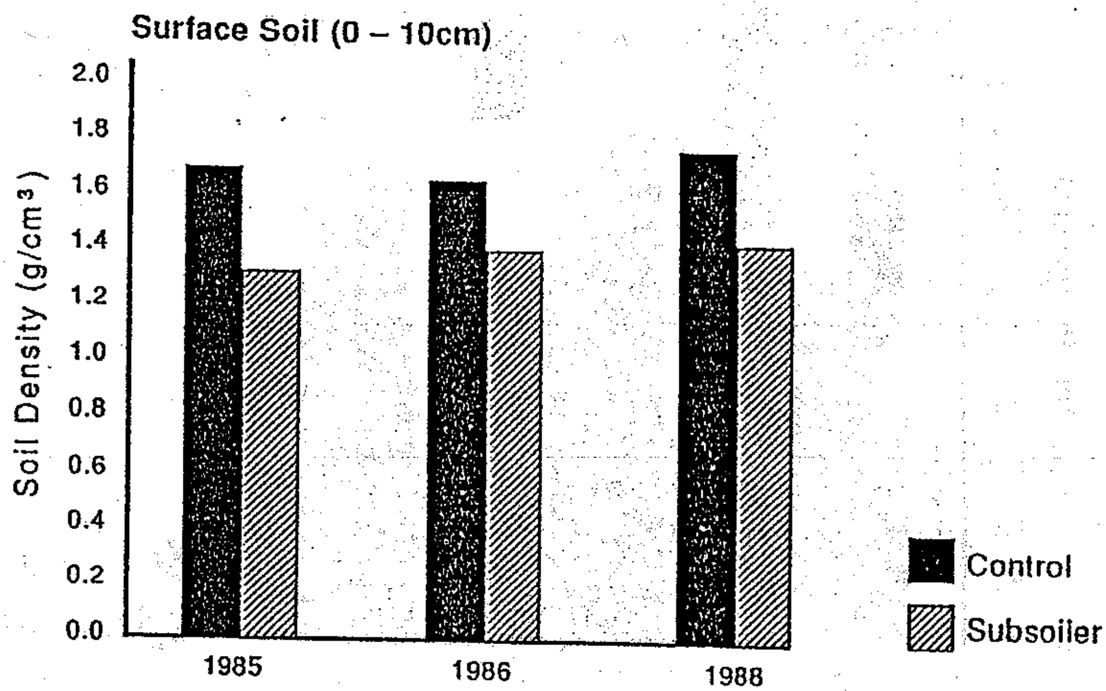

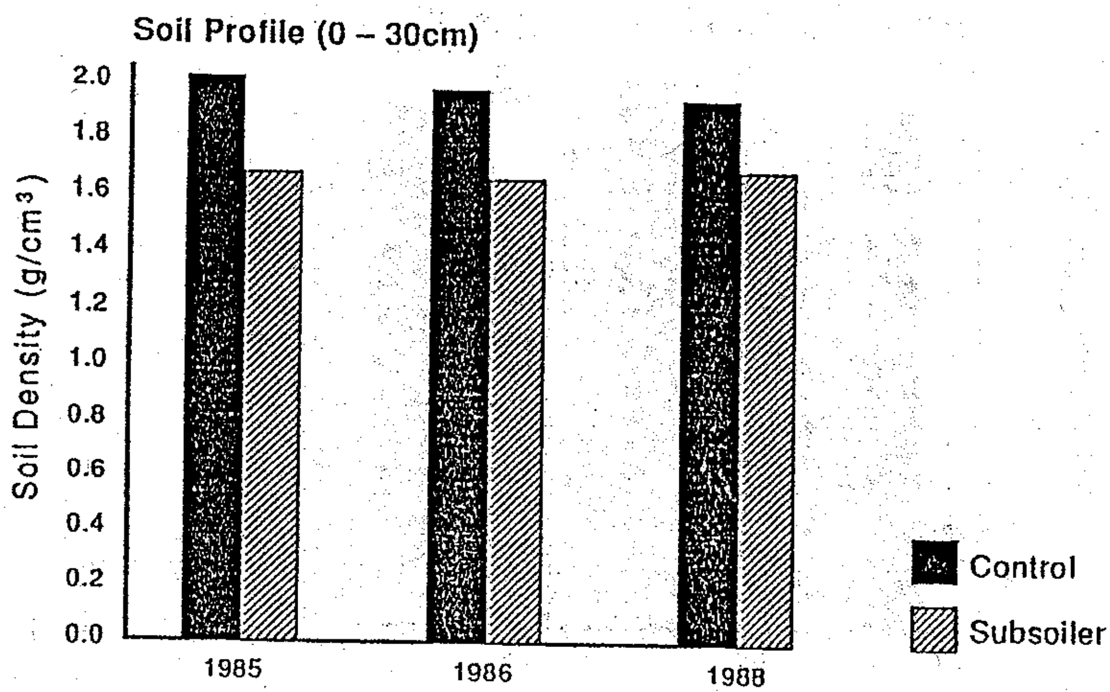

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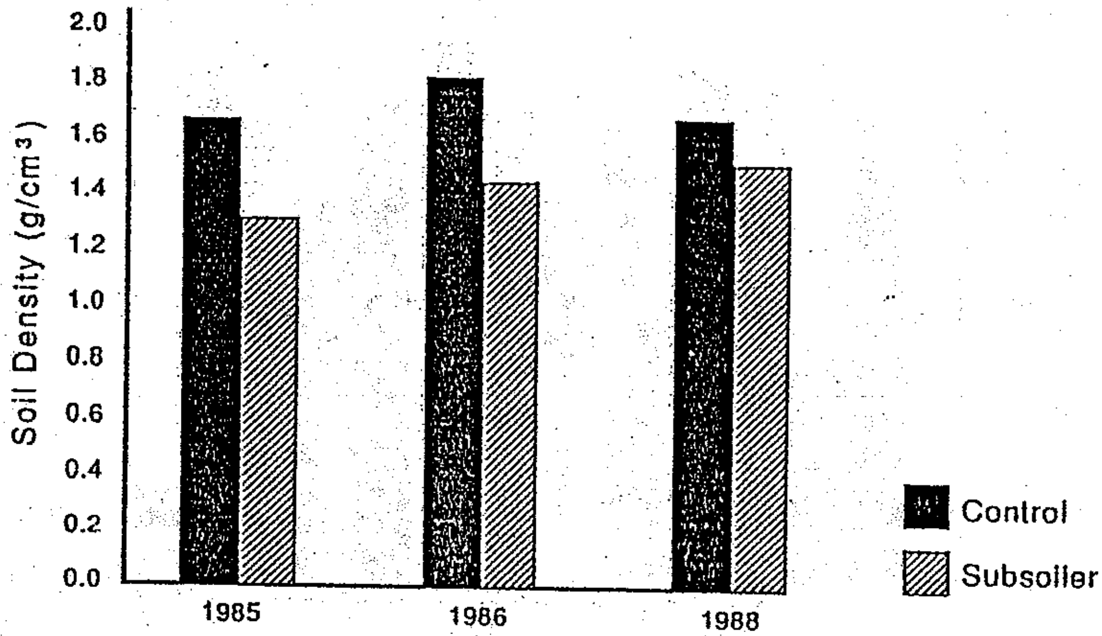
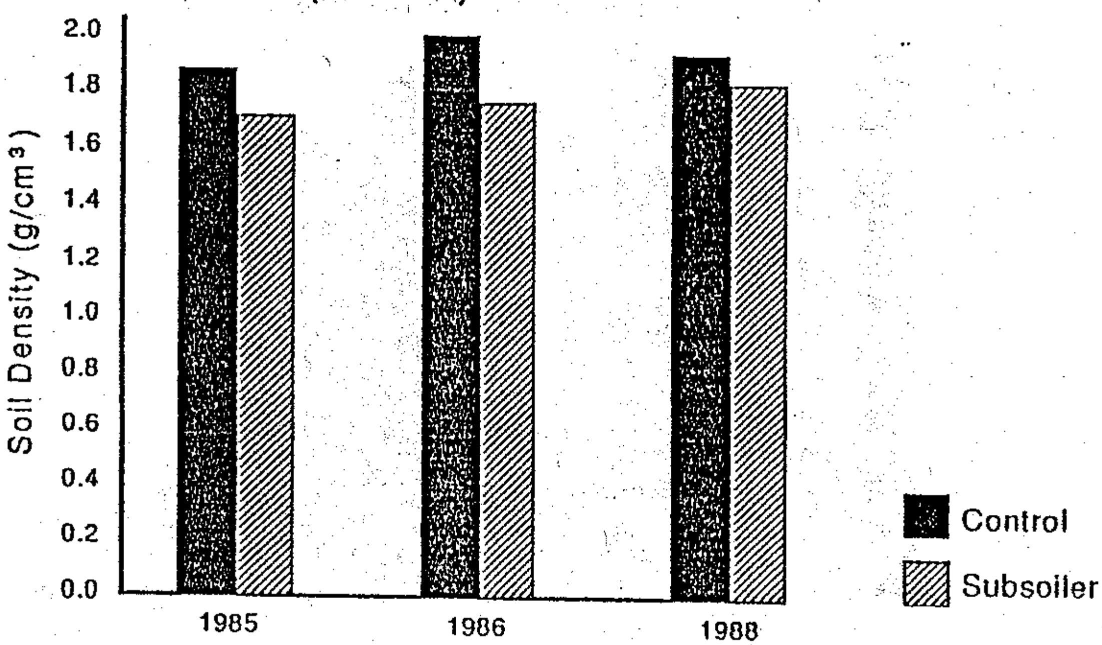
LANDING # 7

Surface Soil (0 – 10cm)



Soil Profile (0 – 30cm)



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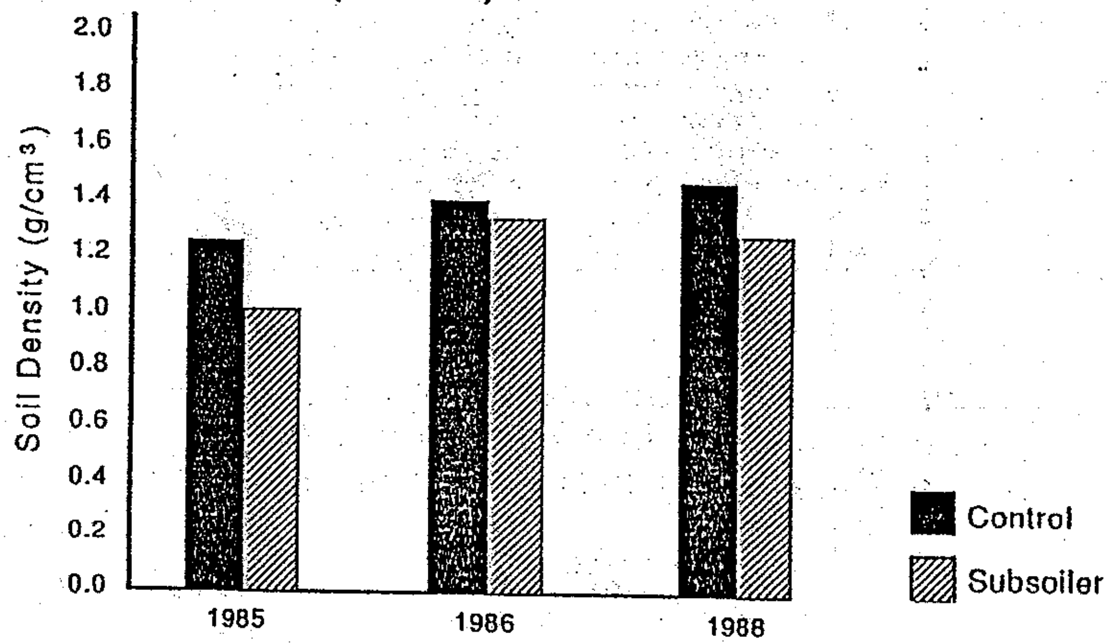

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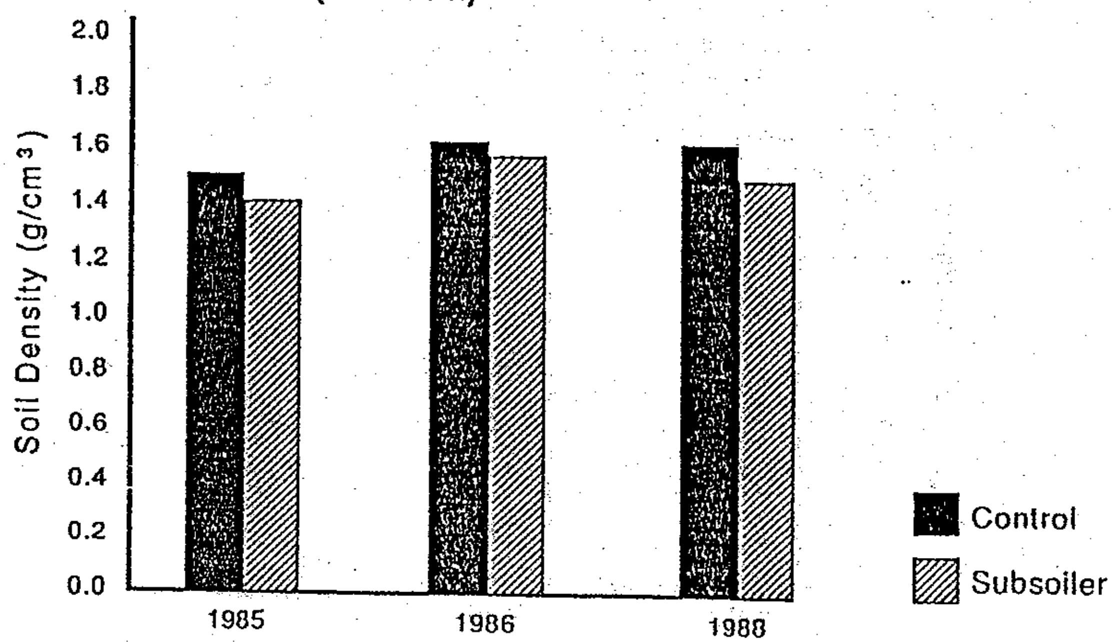

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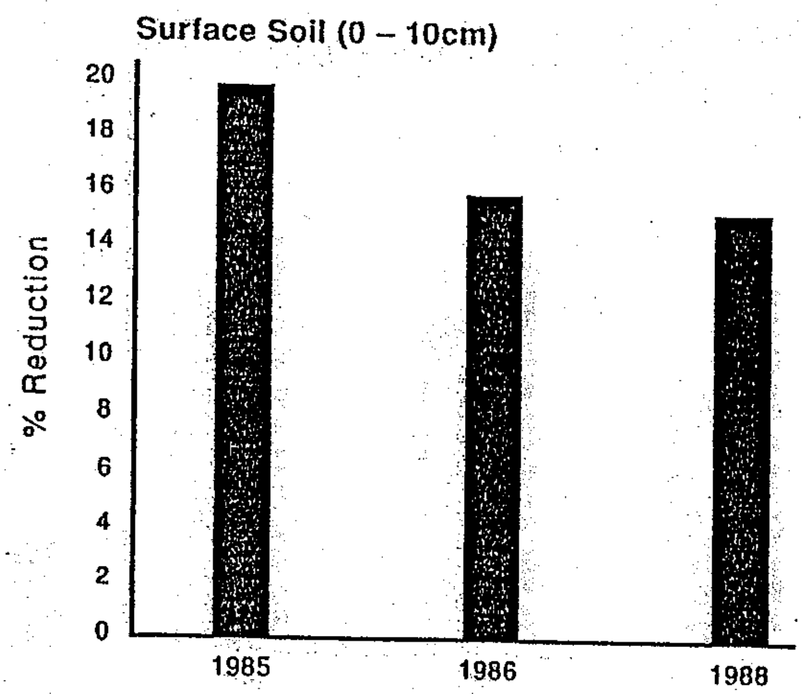

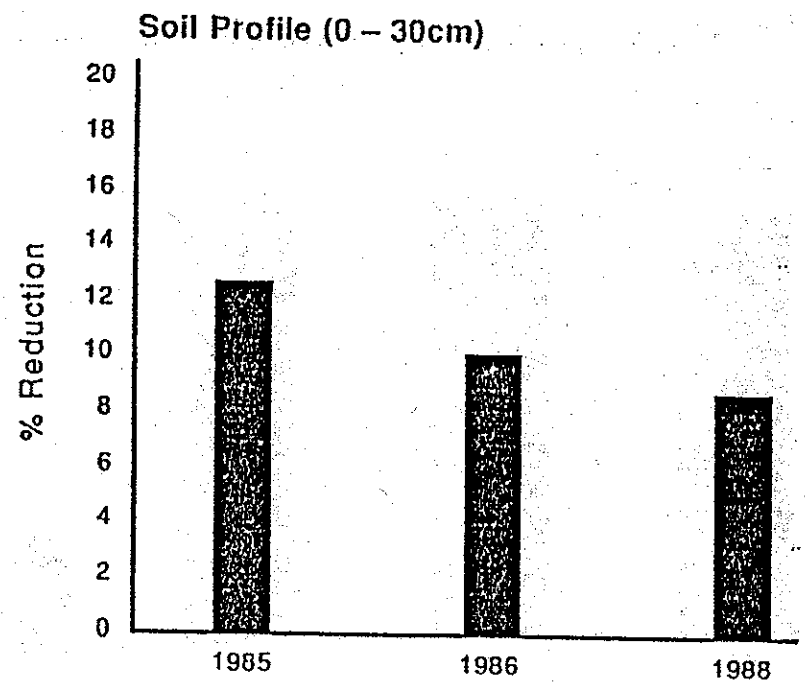

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